A fuzzy expert system in buildings serviceability

PRIETO A. J.[1, a *], MACÍAS-BERNAL J. M.[1,b], ALEJANDRE F. J.[1,c] and SILVA A.[2,d]

[1]ETSIE - University of Seville, Seville, Spain

[2]IST - University of Lisbon, Lisbon, Portugal

[a]ajpi@me.com, [b]jmmacias@us.es, [c]falejan@us.es, [d]anasilva931@msn.com

*corresponding author

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Abstract.
The preservation of the built heritage plays an essential role in the revitalization of current societies, being crucial to their social and economic development. The buildings' service life should be used as a decision criterion in the definition of rehabilitation and maintenance strategies. This study proposes a model to analyse the buildings' serviceability, which is a complex issue, since the functional service life of buildings and components are usually related with subjective concepts and requirements. For this, an expert system called as Fuzzy Buildings Service Life - *FBSL* is proposed, it is a computational tool that applies a fuzzy logic model for estimating the functional service life of the buildings under analysis. The fuzzy inference system (*FIS*) is based on professional expert knowledge and it is implemented in the open access software Xfuzzy 3.0. This model is based on 17 input factors, five related with vulnerability and 12 related with external risks and the model's output is a functionality index. This research represents a new breakthrough in the field of the functional service life prediction, where architectural construction is considered as a single element. The expert system has been normalized through the international standard ISO 31000:2011 (risk management, assessment and analysis). This model was initially applied to 100 heritage buildings (churches built between the 13rd and the 18th centuries) located in Spain, being posteriorly applied to other buildings located in other European regions. In this approach, an example with five monuments is shown. Also the model was validated through the comparison to another service life prediction model, widely used in the literature, ensuring the model's accuracy for ranking buildings' serviceability. This model is able to accurately prioritize proactive rehabilitation actions, which is an essential dimension in order to implement preventive maintenance programs of buildings and architectural heritage sets.

Introduction

Cultural heritage buildings are an important economic and cultural capital of European countries. A monument is more than just the construction itself [1], being part of the local identity and a source of memory of historical events [2]. Therefore, National governments and European institutions increasingly recognise the importance of the conservation of cultural assets [3].

Monuments are undeniable documents of world history. In recent decades, international bodies and agencies have developed various resolutions concerning the commitment for protection, conservation and restoration of monuments. The Athens Convention (1931), The Hague Agreement (1954), the Venice Charter for the Conservation and Restoration of Monuments and Sites (1964) and the Granada Agreement (1985) are a few of the resolutions, in which the protection, study and conservation of the built heritage is the main concern.

Currently, it has been estimated that 50% of all building refurbishments in European cities are related in some way to heritage preservation [4]. The concept of conservation of cultural built heritage has evolved over the recent decades at the international level, in order to define multidisciplinary approaches to intervention in these buildings, increasing their preservation [5]. In the conservation of the architectural heritage, the building should be seen as a whole, thus protecting its constructive system and typological characteristics, maintaining its social function, responding to current lifestyles, avoiding its obsolescence and deterioration [6]. Maintenance activities must be seen as an investment opportunity, adopting a series of measures to prevent both material and functional degradation. Asset managers need to deal with difficult decisions regarding "when" and "how" to repair their building stock [7]. These difficulties are due to the lack of knowledge related to the service life prediction and the absence of methods to assist the asset manager in the definition of a proper maintenance, repair or replacement choices [8]. Consequently, the preservation of architectural assets requires the development of methods, strategies and planning of maintenance operations [9]. In the area of the methodologies for predicting service life of buildings, Silva et al. [10] has developed extensive contributions on façades claddings applying several kind of methods: deterministic, stochastic, computational and factorial models. However, do not exist many contributions in the literature about the functional service life of built heritage where the monuments are analysis as a whole.

Aim

In this study, a methodology for the evaluation of the physical and functional condition of architectural heritage is proposed. This evaluation precedes decisions for preventive maintenance actions, avoiding the destruction of architectural characteristics in the name of conservation. A fuzzy inference system (FIS) is developed in order to model the functional service life of heritage buildings, providing a priority ranking of maintenance actions related with the performance of the case studies under analysis. This fuzzy model will support decision-makers in developing the most appropriate strategy for the future use of homogeneous sets of built heritage, considering the most relevant factors involved, and applying efficient preventive maintenance strategies.

Functional Service Life Model

Assessing serviceability in terms of the service life of built heritage and its relationship with the environment is undoubtedly a complex system of relationships between different factors, which usually requires the opinion of professional experts in the field. In these types of situations, in which different assessments of the input parameters are possible, traditional logic are usually unable to provide the appropriate answer to the problem under analysis. The fuzzy set theory has been widely applied as a support tool for decision-making processes and in performance evaluation in engineering [11, 12]. One of the main advantages of the application of fuzzy sets is the ability to treat uncertainty, vagueness and imprecision. In this study, the loss of functionality of the monumental buildings is analysed based on the fuzzy logic principles established by Zadeh [13].

In this sense, a fuzzy model was proposed, called as Fuzzy Building Service Life (*FBSL*). This model is an accurate tool, translating the functional condition of the cases studies analysed, encompassing all the variables that influence the functionality of buildings. In general, these kind of fuzzy expert systems are structured in four stages: i) "fuzzification", in which input values, subject to certain imprecision and subjectivity, are represented by fuzzy sets; ii) knowledge-based information; iii) "inference" stage, in which fuzzy rules are defined such as modus ponens propositional inference rules (IF "fuzzy proposal" AND "fuzzy proposal" THEN "fuzzy proposal"); and iv) "defuzzification", which is used to generate specific output values. The *FBSL* can be used to establish the probable loss or gain in functional service life of a building's components for various levels of maintenance. This model has been implemented in open access software. The computational application of the fuzzy model used in this study was implemented in fuzzy logic software developed at IMSE-CNM - Seville Institute of Microelectronics and National Microelectronics Centre and R&D&I centre belonging to CSIC - Spanish National Research Council. It is named Xfuzzy3.0 [14].

For designing the model, an expert survey, with 15 professional experts, was used; the experts consulted had the following profiles [15]: two Professors of Rehabilitation and Pathology; and architect; a director of an accredited laboratory of building materials; a businessman working for a construction company; a restoration artist; a technical architect; and an archaeologist (all with recognized professional experience of more than 20 years); two fireman commander from Seville and Madrid; the director of a World Heritage conservation building; the head of building maintenance of a municipality provincial capital of 700,000 inhabitants; the person in charge of the conservation of a Port Authority; an expert in quality management in buildings, with numerous publications on this subject and the director of an insurance company at the international level.

This expert system was developed by identifying a total of seventeen input parameters, specifically vulnerability factors and static-structural, atmospheric and anthropic risk factors validated and ranked by a group of experts, closely related to the output parameter of the model (the functional service life of buildings). Therefore, this study intends to contemplate all the relevant variables, in order to describe the loss of functionality of heritage buildings. The following documents were reviewed for defining the input parameters: National Cathedral Plan [16]; Law on Construction Planning [17]; Heritage Conservation Network [18]; Technical Building Code [19]; UNE 41805:2009 IN [20]; ISO 15686 [21]. The system records minor fluctuations in the values of each input parameter, which are translated into positive or negative variances in the output values of the model. The qualitative and quantitation factors' valuation is explained in Table 1.

Table 1 Descriptive variables valuation of the *FBSL* model

Variables	Variables designation	Qualitative valuation	Quantitative valuation	Descriptive valuation of the input parameters
		Good	1.0	Optimum ground conditions (very stable soil - rock bottom)
v_1	Geological location	Average	2.5	Ground conditions within acceptable limits of stability
		Bad	4.0	Very unfavourable ground conditions (clay soil)
		Good	1.0	Easy and fast evacuation of water on deck (ideal situation - semi-spherical dome)
v_2	Roof design	Average	4.5	Good conditions in terms of evacuation of rainfall
		Bad	8.0	Complex and slow evacuation of water
		Good	1.0	Building without constructions around it
v_3	Environmental conditions	Average	4.5	Building between constructions
		Bad	8.0	Building between complex constructions
		Good	1.0	Uniform characteristics of constructive system
v_4	Constructive system	Average	4.5	Heterogeneous characteristics of constructive system
		Bad	8.0	Intermingled different constructive system
		Good	1.0	Optimal state of conservation
v_5	Preservation	Average	4.5	Normal state of conservation
		Bad	8.0	Building in a neglected state of conservation
		Good	1.0	Without any apparently modification
r_6	Load state modification	Average	4.5	Symmetric and balanced modifications
		Bad	8.0	Disorderly modifications without any pattern
		Good	1.0	Live loads below the original level
r_7	Live loads	Average	4.5	Live loads equal to the original level
		Bad	8.0	Live loads higher than the original level (warehouse)
		Good	1.0	Natural cross-ventilation in all or in several areas
r_8	Ventilation	Average	4.5	Natural cross-ventilation in some areas
		Bad	8.0	No natural cross-ventilation
		Good	1.0	All facilities are in use and under standards conditions
r_9	Facilities	Average	4.5	Some facilities are in use
		Bad	8.0	Facilities are not ready to be used
		Good	1.0	Incombustible structure and low fire load
r_{10}	Fire	Average	4.5	Combustible structure and medium fire load
		Bad	8.0	Combustible structure and high fire load
		Good	1.0	Low level of health, cleanliness and hygiene of the building's spaces
r_{11}	Inner environment	Average	4.5	Medium level of health, cleanliness and hygiene of the building's spaces
		Bad	8.0	Maximum level of health, cleanliness and hygiene of the building's spaces
		Good	1.0	Area with low annual rainfall
r_{12}	Rainfall	Average	4.5	Area with medium annual rainfall
		Bad	8.0	Area with maximum annual rainfall
		Good	1.0	Area with low temperature differences
r_{13}	Temperature	Average	4.5	Area with medium temperature differences
		Bad	8.0	Area with maximum temperature differences
		Good	1.0	Population growth greater than 15%
r_{14}	Population growth	Average	4.5	Population growth 0%
		Bad	8.0	Population growth less than 5%
		Good	1.0	Properties with great historical value
r_{15}	Heritage value	Average	4.5	Properties with average historical value
		Bad	8.0	Properties with low historical value
		Good	1.0	Social, cultural and liturgical appreciation (high value)
r_{16}	Furniture value	Average	4.5	Social, cultural and liturgical appreciation (average value)
		Bad	8.0	Social, cultural and liturgical appreciation (low value)
		Good	1.0	High activity in the building (high occupancy)
r_{17}	Occupancy	Average	4.5	Media activity in the building (average occupancy)
		Bad	8.0	Low activity in the building (low occupancy)

ISO 31000 Risk Management Standard and the *FBSL* Methodology

The ISO 31000 [22], designed by the private organization International Organization for Standardization (ISO), is a powerful tool applicable to any organization engaging in the implementation and improvement of the risk management process. This process simplifies the decision-making process, evaluating the uncertainty associated with the phenomena under analysis, also providing policies, procedures and provisions for the integration of risk management at all levels of the organization. The standard has been developed as a common understanding and effective agreement for generating the necessary steps to adequately identify, manage and evaluate risk, the latter being defined as a “combination of consequences between events associated with a probability of future occurrence” ISO 31000 and ISO Guide 73:2009 [23].

The *FBSL* model complies with the ISO 31000 risk management standard, and is a very easy way for users to fulfil the requirements proposed in the standard, through risk management, assessment and analysis, contributing effectively and efficiently to the preventive conservation of architectural heritage [24]. In this sense, the methodology is conformed to all the requirements established by the international standard (ISO 31000): a) communication and consultation; b) establishing the context; c) risk assessment; d) risk treatment; e) monitoring and review (Fig. 1).

With this procedure, it is possible to manage architectural heritage site in order to monitoring and their conservation state over time. Thus, the serviceability method is used to obtain a hierarchical classification for the priority of intervention in the built heritage, through the probabilistic estimation of the service life of homogeneous architectural sites. Based on the functional durability of heritage buildings, it is possible to define three levels of priority: a) an upper level, where the risk of failure is regarded as intolerable, thus requiring an immediate intervention; b) a middle level or “grey” area, where costs and benefits are taken into account and balanced; c) a lower level, where the risk is regarded as negligible or so small that it is only necessary to monitoring the buildings, do not requiring any intervention.

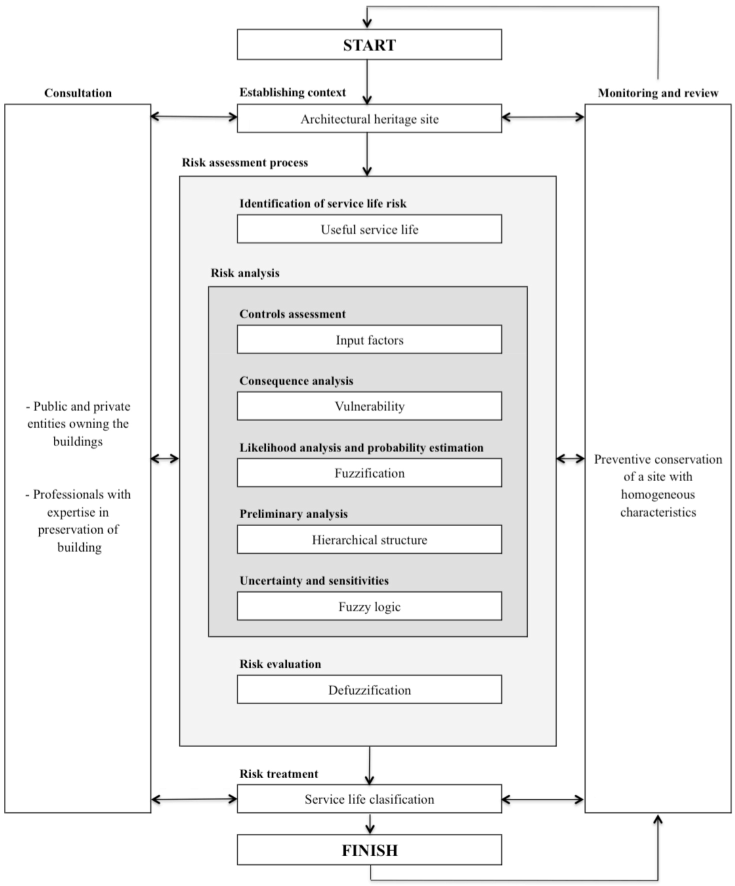
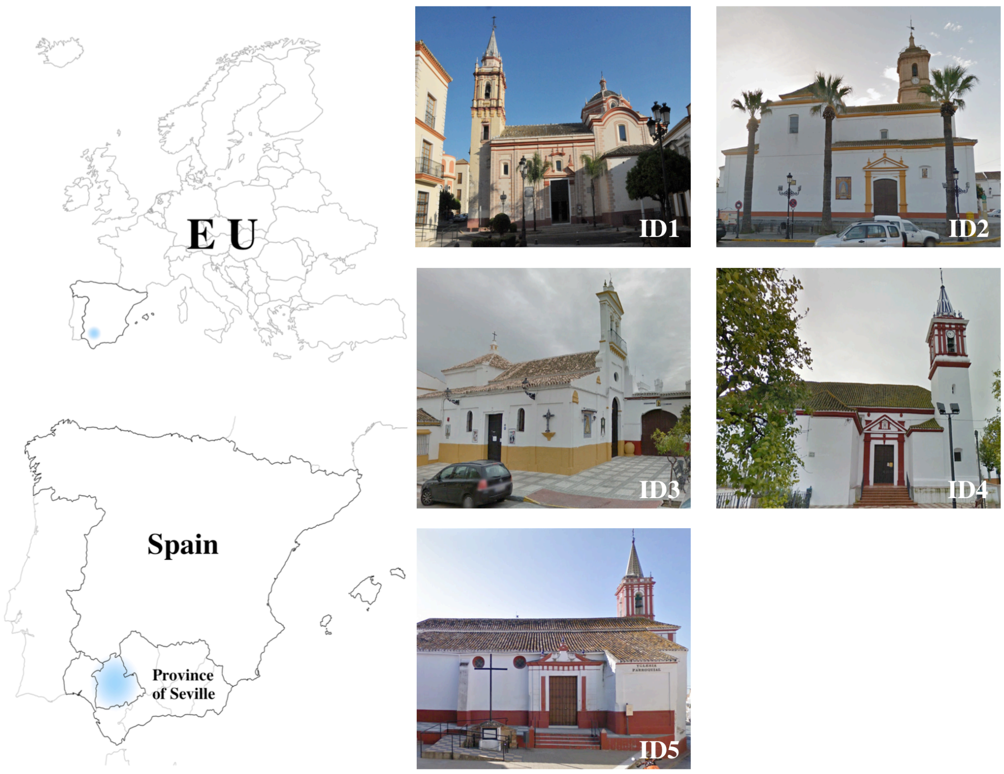


Fig. 1 *FBSL* adjustment to ISO 31000 [24]

Case Studies

It is really significant to understand the difference between the detailed approaches used for a singular building and those methods most efficient for larger scale analysis of groups of buildings, as it is the case of this study. However, when increasing the amount of buildings and enlarging the area to be assessed, the resources and quantity of information required also increased, so it is necessary to resource to grouping of building typologies and constructive characteristics. This study is focused on a set of built heritage located in South Spain, in the province of Seville, (Spain), in an area over 14,000 km^2. The geographical area extends close to the mouth of the Guadalquivir River (Southwest) until the mountains of the region on the North (Fig. 2). This territory presents a warm Mediterranean weather with an annual average temperature of 18.5ºC; winters are generally mild. These set of historical constructions were built between the 13th and 18th centuries. Most of these churches were built in the Middle Ages and their architectural style was a unique Spanish artistic movement since it was influenced by both Islamic and Gothic Christian elements. These churches are morphologically characterized by this stylistic dualism: a vaulted Gothic apse and a body of three naves with a timber roof (collar beam in the main nave) of Moorish origin [25]. Its brick walls are complemented with quadrangular or sometimes octagonal pillars and with raised brick mouldings as decoration. Among other elements of particular interest, funeral chapels have been successively added to the side naves, which on some occasions, are housed in remaining sections of pre-existing mosques [26]. The predominant materials used in the monuments studied in the province of Seville were rammed earth, bricks, limestones, mortars and marbles [27]. In the Gothic-Mudejar churches we find either stonework, brickwork and rammed earth as the vertical supporting structure, horizontal wooden covering with jointed rafters, and a finishing consisting of ceramic tiles on top. The foundations are made with non-stop ditches of bricks or stones. On the pilasters, the foundations are made of brick or stone spread footing. The five case studies under analysis are shown in Fig. 2.



ID1 - San Martín de Tours' parish church (Bollullos de la Mitación); ID2 - Santa María Magdalena's parish church (Villamanrique de la Condesa); ID3 - Nuestra Señora de la Antigua's parish church (Almensilla); ID4 - San Miguel Arcángel's parish church (Castilleja del Campo); ID5 - San Martín de Tours' parish church (Carrión de los Céspedes)

Fig. 2 Location of the built heritage in South Europe, Spain; and heritage buildings chosen for studying in the Province of Seville, South Spain

Results and Discussion

Application in Architectural Heritage. The fuzzy expert system (*FBSL*) has been applied to a considerable set of built heritage, with homogeneous constructive characteristics, in southern Spain. In this approach, an example of five parish churches is shown. Table 2 presents the valuation of the variables introduced into the fuzzy system (Fig. 3). A ranking of the functionality values of each building, and their relative position in the heritage set, is obtained. This hierarchical classification of priority actions ranks in the first place the buildings with lower functionality scores, and therefore requiring immediate actions, and in last place orders the buildings with better functional level. The model works as an indicator of the priority of intervention, analysing the evolution of the functional service life of buildings, resulting in a classification and scheduling of maintenance actions to be performed in a set of churches or other heritage buildings, rationalizing and optimizing the conservation operations.

Table 2 Assessment of the homogeneous heritage site through input factors

ID - Built heritage	Vulnerability					Static-structural risks						Atmospheric risks		Anthropic risks			
	v_1	v_2	v_3	v_4	v_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	r_{17}
1	1.0	2.0	4.0	3.0	2.5	3.0	6.0	4.0	4.0	6.0	3.0	4.5	3.5	4.0	4.0	4.0	5.0
2	1.0	2.0	3.0	3.0	3.0	3.5	4.5	5.0	4.0	3.5	3.0	4.0	3.5	4.0	3.0	3.0	4.0
3	1.0	2.0	6.0	4.0	2.0	4.0	6.0	4.0	2.0	6.0	3.5	4.0	3.5	4.0	4.0	4.0	6.0
4	1.0	2.0	2.5	2.5	2.0	3.5	3.5	5.0	3.5	3.5	3.0	4.0	3.5	4.0	3.0	2.5	4.0
5	1.0	2.0	3.0	3.0	2.0	3.0	4.0	5.0	4.0	3.0	3.0	4.5	3.5	4.0	4.0	4.0	5.0

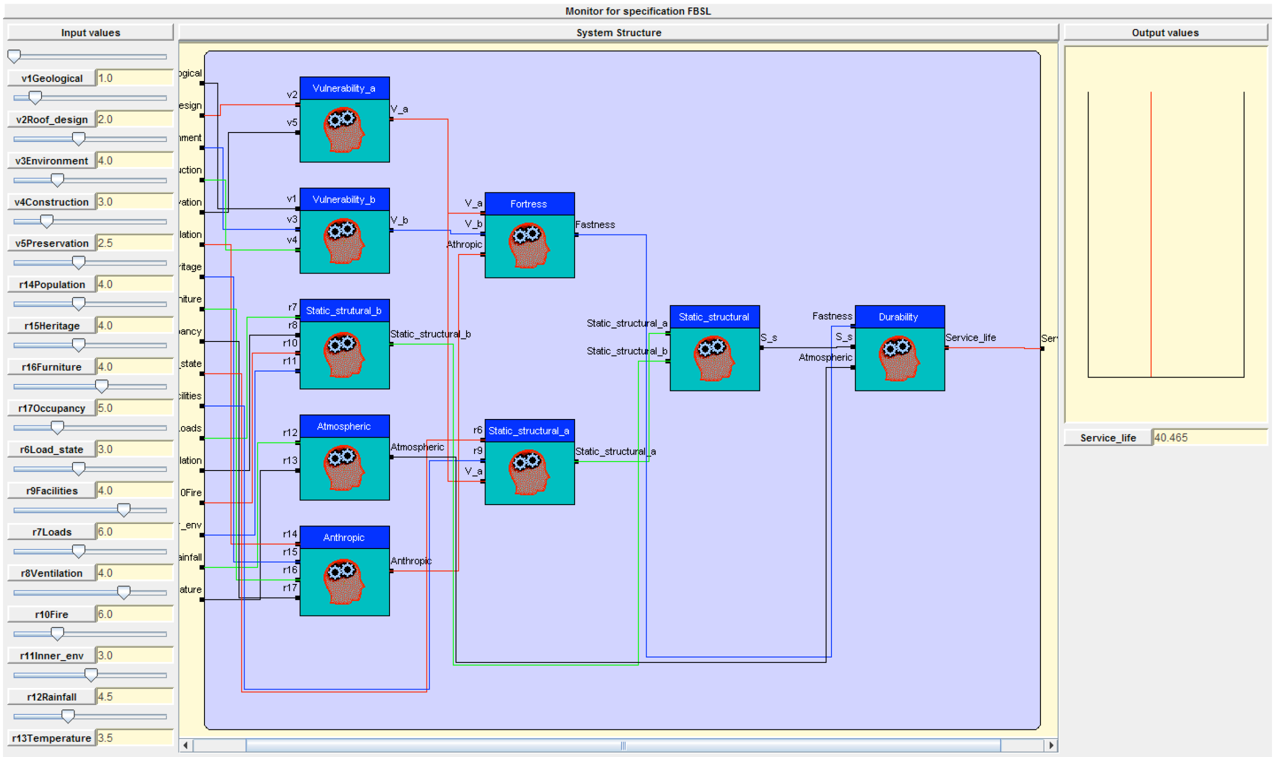


Fig. 3 Screen shot of the *FBSL* method. Functionality level of the parish ID1

The method presented in this study is based on a systematic evaluation of the functionality and the visual degradation of the buildings as a whole. This methodology considers the consequences of environmental, static-structural and anthropogenic conditions on the functional service life of cultural heritage (given by the serviceability index - *FBSL*).

During the valuation of the 17 input factors, the variables v_1, v_2, r_{13} and r_{14} with the same value were considered. That happens because although, each building has own vulnerabilities and risks associated, in sets of buildings with homogeneous constructive characteristics, social and environmental features could be common for some of them. In this approach, the five constructions selected, the variable v_1 - (geological location) with an optimum ground conditions were considered because not significant fractures in the structure system were observed. Variable v_2 – (roof design) with a valuation between "Easy and fast evacuation of water on deck" and "Good conditions in terms of evacuation of rainfall" was valuated, because the cover presented enough conditions in order to water evacuation. The atmospheric risk r_{13} - (temperature) in an area with medium temperature differences measured were valuated, because the set of buildings are located in South Europe area, near to the Guadalquivir valley climatic zone where do not exist extremely variations in temperatures. Finally, the input factor r_{14} – (population growth), this variable with a 0% of variations was valuated.

After the variables valuation in the expert system a classification of the sets of constructions is obtained. This ranking related with the functional service life of a group of five heritage buildings is shown in the Table 3. The goal of this study is to determine the relative position of certain buildings with respect to others, thus determine which building must be intervene at first, optimizing preventive maintenance plans for a large set of heritage buildings, avoiding unnecessary costs related with the preservation of built heritage. In this approach, the parish church ID1 (San Martin de Tours' parish church) located in Bollullos de la Mitación with a functional level of 40.5 points, it should be the first buildings for considering review in order to establish possible future refurbishment actions.

Table 3 Functional ranking of the architectural heritage constructions

Classification	ID	Parish Church	Location	Functionality index (*FBSL*)
1st	1	San Martín de Tours' parish church	Bollullos de la Mitación	40.5
2nd	3	Nuestra Señora de la Antigua's parish church	Almensilla	46.0
3rd	5	San Martín de Tours' parish church	Carrión de los Céspedes	50.0
4th	2	Santa María Magdalena's parish church	Villamanrique de la Condesa	59.5
5th	4	San Miguel Arcángel's parish church	Castilleja del Campo	61.5

FBSL: Fuzzy Building Service Life

These results show that the church with ID1, located at the top of the functionality ranking need more attention in terms of periodical inspections than the other buildings considered. The building ID4 at the bottom of the classifications is positioned, which is the building with the best functional level in relation with the set under analysis. In Fig. 4 the current conservation state of ID1 and ID4 are shown, it is possible to perceive in the building ID1 some degradation on the façades due to atmospherics external actions and even in the cover, where biological colonization is presented by miscellaneous plants, among other living beings (pigeons). As it is known the roof of the buildings is one of the most vulnerable parts of the constructions much more in historical building in which most of them the cover was built with timber. This constructive material is exposed to several affections, i.e. atmospheric risks (rain or temperature are ones of the mains agents in the degradation of this kind of elements) and also xylophage actions. In fact, the occurrence of anomalies in roofs usually leads to structural problems in the roof itself and in the rest of the building, and even damages in furniture and goods inside the religious buildings.

Maintenance activities should be based on reliable data regarding the priority of intervention in the building stock, therefore considering technical information regarding the building's deterioration rate, the costs towards functional information on the building's performance and the in-use costs. These kind of approach can provide relevant information when a set of buildings are analysed, giving knowledge regarding which building should be subjected to preventive conservation actions before another one. It is a difficult task in order to analyse a monument as a whole, where the intrinsic vulnerabilities and the influences of many external risks are being considered. In these terms, even if a building is in a very good vulnerability condition, could be affected by many other kinds of external variables, which ranks the construction with a lower serviceability level than another located in better exterior conditions. In relation with that, the

degradation mechanisms represent the progression of changes to which the constructions are subjected during them service life leading to a deterioration of its functional and physical properties.
However, when these heritage constructions are subjected to refurbishment actions those are due to subjective reasons, such as programmatic or aesthetic reasons (in wealthier buildings); conversely, buildings with high degradation may not be subjected to maintenance actions due to the scarcity of resources. In some cases, when there are not available funds, the restoration occurs many years later, which also reveals the subjective criteria that affect the decision of intervening.

The functional service life model has been successfully applied in the definition of maintenance strategies for heritage sites. The fuzzy system provides indications regarding the definition of maintenance plans. This information is crucial in the implementation of maintenance programs in large building stocks. Furthermore, the knowledge obtained in this study will make it possible to develop paths to support decision-making and to optimize maintenance works in terms of the best time to perform them, also including in the analysis the cost constraints. This study could be extended to other buildings and components, and can also be adjusted to different environmental contexts.

Fig. 4 Current state of ID1 San Martin de Tours' church (Bollullos de la Mitación) and ID4 San Miguel Arcángel's church (Castilleja del Campo)

Correlation between Functional and Physical Service Life Models. In order to validate the model, and intending to evaluate the applicability of the model to current buildings, the functional service life model (*FBSL*) has been also established in correlation with a physical degradation model (S_w) applied on stone claddings [28]. In this study, both methodologies are applied to 203 natural stone claddings, located in the Lisbon area, Portugal. The functionality and degradation condition of the façades analysed are evaluated through visual inspections. Vulnerability and risk (intrinsic and extrinsic variables) are considered in the evaluation of both methods. This information is extremely important in the implementation of maintenance programs in large building stocks.

The degradation condition of the stone claddings was analysed during an extensive fieldwork. As mentioned by Ortiz et al. [29], in the definition of preventive maintenance policies and in the analysis of built heritage conservation, it is essential to evaluate the vulnerability matrix and its relationship with static and structural risks. Therefore, in this study and based on the buildings' characteristics, 17 input factors of fuzzy model *FBSL* (5 vulnerability variables and 12 risks variables) were evaluated (Table 1) [30, 31]. After quantifying the input factor values, a ranking of the sample was obtained. The building facades with lower *FBSL* are at the top of this ranking, which means that these facades need an urgent intervention, in order to restore an adequate functionality level. On the other hand, facades with higher *FBSL* are at the bottom of this ranking (the facade does not need priority maintenance actions) [32].

The correlation between both indexes was inversely proportional (Fig. 5), with a Pearson correlation coefficient (*r*) of -0.824 (revealing a very strong correlation between both indexes). This means that higher degradation levels correspond to lower functionality indexes, and vice-versa.

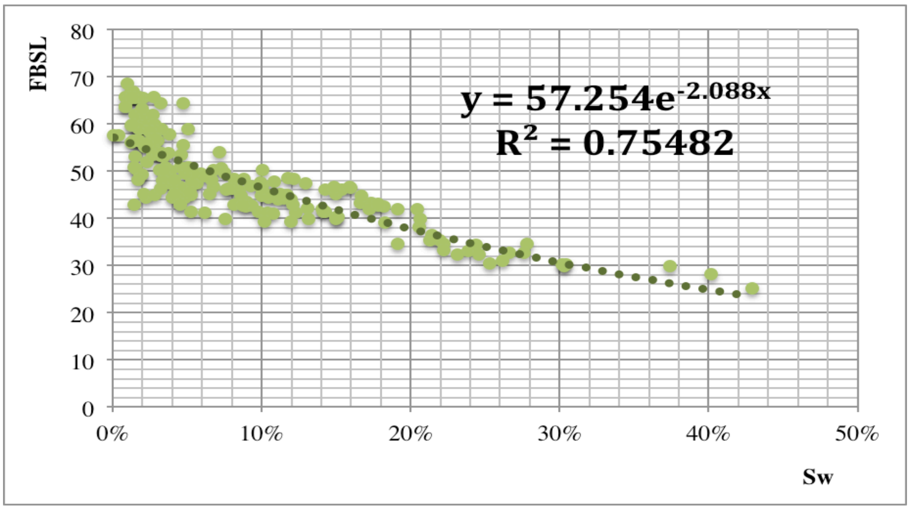


Fig. 5 Degradation and functionality in natural stone claddings, based on 203 case studies [31]

As mentioned by Aikivuori [33], the critical loss of performance is usually influenced by subjective perception of the building, and the technical or economic criteria are usually neglected in the decisions made on building refurbishment. Naturally, an increase of the physical degradation of claddings leads to a decrease of the functional performance of buildings, since the serviceability is intrinsically related with the expectations and requirements of the buildings users. Although they are distinct concepts, the physical and the functional service life can be correlated and it can be said that the physical deterioration usually leads to the functional loss of performance, influencing the end of the buildings' functional service life. The opposite is not entirely true, since even if the building presents an acceptable physical condition, with no visible degradation, the end of their functional service life may occur anyway due to changes in users' demands. Analysing a couple of case studies in Fig. 5, in a façade with degradation (S_w) equal to around 37% the functionality (*FBSL*) is around 30. The second façade has degradation (S_w) around 10% and its functionality (*FBSL*) is within the range 39-50. The analysis of the determination coefficient (R^2), which evaluates the proportion of variance of the *x* values (*FBSL*) related to *y* (S_w), reveals a determination coefficient (R^2) of 0.756, based on an exponential curve obtained ($y = 57.244e^{-2.087x}$), which implies a strong correlation between the two variables considered (functional and physical service life).

The *FBSL* model has been successfully applied in the definition of maintenance strategies for heritage sites [15]. In this study, the efficiency of the *FBSL* model in building sets without heritage characteristics was corroborated. This study shows that the *FBSL* index can be used in other architectonical sets with similar characteristics, in other social and environmental contexts.

Conclusions

The methodology proposed in this study was developed as a basic instrument for predicting the functional service life of building components in failure conditions for maintenance purposes. The models and results achieved can be very useful in the management and organization of preventive maintenance-oriented activities in buildings, taking into account the financial, social and environmental needs, since the built heritage is an important issue in terms of preserving the culture of the current societies.

In this study, the functional service life of 5 parish churches in the Province of Seville (South Spain) was determined in based on a fuzzy inference system for predicting serviceability of buildings.

The modelling of the functional service life is a complex task and cannot be defined by simple mathematical functions. The system has been standardised with the specifications of the international standard ISO 31000:2011 risk management standard, and is a very easy way for users to fulfil the requirements proposed in the standard, through risk management, assessment and analysis, contributing effectively and efficiently to the preventive conservation of monuments. Therefore, in order to validate the proposed model, a relationship between a functional index (*FBSL*) and a quantitative index, associated with physical service life and degradation of building elements (S_w), is established. A strong relationship between the two indexes considered was obtained (with a determination coefficient of 0.756), revealing an inverse correlation between the two indexes. Consequently, the results obtained shown that, as expected, as the degradation increases, the values of the *FBSL* also decrease.

The proposed methodology intends to be a simple and cost-effective tool to determine the functional service life of monuments in a whole region, establishing a prioritization of the maintenance operations in groups of monuments with similar constructive characteristics, trying to focus the attention on the buildings with lower functionality levels (which require higher conservation efforts and urgent interventions). This approach provides some guidance regarding the risks and vulnerabilities that should be carefully analysed in order to minimize the degradation of cultural heritage and their risk of failure. The performance-based prioritization of building maintenance is an essential asset for a more rational and sustainable use of economic resources.

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